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This article was submitted to
World Congress on Medical Physics & Biomedical Engineering
Sydney, Australia
August 23-30, 2003

August 11, 2003

U.S. Department of Energy

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Radiation Phantom with Humanoid shape and Adjustable Thickness (RPHAT)

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Abstract

A new radiation phantom with humanoid shape and adjustable thickness (RPHAT) has been developed. Unlike the RANDO[®] Phantom which is a fixed thickness, this newly designed phantom has adjustable thickness to address the variable thickness of real-world patients. RPHAT allows adjustment of the body thickness by being sliced in the coronal direction (as opposed to axial). Center slices are designed such that more sections can be added or removed while maintaining the anthropomorphic shape. A prototype of the new phantom has been successfully used in a study investigating peripheral dose delivery, where the amount of scatter within the patient, and therefore the patient thickness, plays a critical role in dose deposition. This newly designed phantom is an important tool to improve the quality of radiation therapy.

Introduction

The most widely used anthropomorphic phantom for clinical quality control and research in radiation therapy is the RANDO phantom¹⁻⁶. It is constructed with a natural human skeleton cast inside material that is radiologically equivalent to soft tissue. Low-density material is used to simulate lungs. The phantom is axially sliced into 2.5 cm sections with optional hole grids to hold dosimeters. The two available models correspond to the “standard” man and the “standard” woman. However, in the real-world, many radiotherapy patients do not correspond to those body shapes and sizes, being either overweight as the general American population gets more obese or, in some cases, cachectic as a consequence of their cancer. Dosimetry depends upon the *precise* amount of patient tissue located along the path length of the particles. Therefore, if the point of interest is located outside of the field, the patient’s thickness is a critical factor in accurate dose determination. A new anthropomorphic phantom was developed to address the deficits of a fix thickness phantom. The new phantom is of humanoid shape with an adjustable thickness through the insertion or removal of a variable number of tissue-equivalent slices. A prototype has been built and tested. It provides a robust new model for radiation studies.

Methods and Materials

The new Radiation Phantom with Humanoid shape and Adjustable Thickness (RPHAT) is a tissue-equivalent anthropomorphic phantom sliced in the coronal direction, which is designed for radiation oncology use. The central slices are shaped to allow a variable number of sections to be inserted while maintaining the

anthropomorphic shape (Fig 1). A prototype of RPHAT was produced by the manufacturer of the RANDO® Phantoms (The Phantom Laboratory, Greenwich, NY) (Fig. 2, 3). It consists of homogeneous tissue equivalent material of the same type that is used for RANDO® phantoms. “Bones”, “lungs” and dosimetry ports were not included in this prototype, but future models could easily accommodate these additional features. In the prototype each of the central slices is 2.5 – 2.7 cm thick, with a possibility of inserting up to five of them. Therefore, anthropomorphic phantoms ranging in total thickness from 18.1 cm to 30.7 cm can be generated from this single base structure.

RPHAT has been successfully used in a study to investigate the capability of a Monte Carlo system to simulate dose delivery in a multibeam treatment outside of any of the primary beams⁷. Since no primary beam reaches the points of interest in the given situation and therefore all of the dose is due to scatter, the amount of scatter material is crucial. RPHAT allows the determination of the relationship between the scatter dose outside the beam and the patient thickness. Such an investigation would not have been possible with previous phantoms.

Summary

The new phantom is a valuable addition to the tool chest of medical physicists, which allows quality assurance measurements for a variety of patient thicknesses. For research purposes, RPHAT also allows for the investigation of the influence of patient thickness as an independent dosimetry parameter. Outside of the primary beam, scatter dose from within the patient is the main source of radiation to the peripheral tissues.

Although single-beam measurements can be obtained using a slab-shaped phantom, for multiple beam treatment, it is necessary to use an anthropomorphically shaped phantom to properly model the true scatter pathways. Inpatient scatter is an important area of research as it represents a significant portion of the dose delivered from an IMRT plan, as well as being a critical component in other radiation related research. Thus, a phantom that is both humanoid and adjustable in thickness is required. RPHAT will help to meet the increasing demand for accurate, patient specific dosimetry for both clinical and research purposes.

Acknowledgements

This work was performed under the auspices of the U.S. Department of Energy by University of California Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48. This research was supported by the Office of Science (BER), U.S. Department of Energy, Grant No. DE-FG03-01ER63237.

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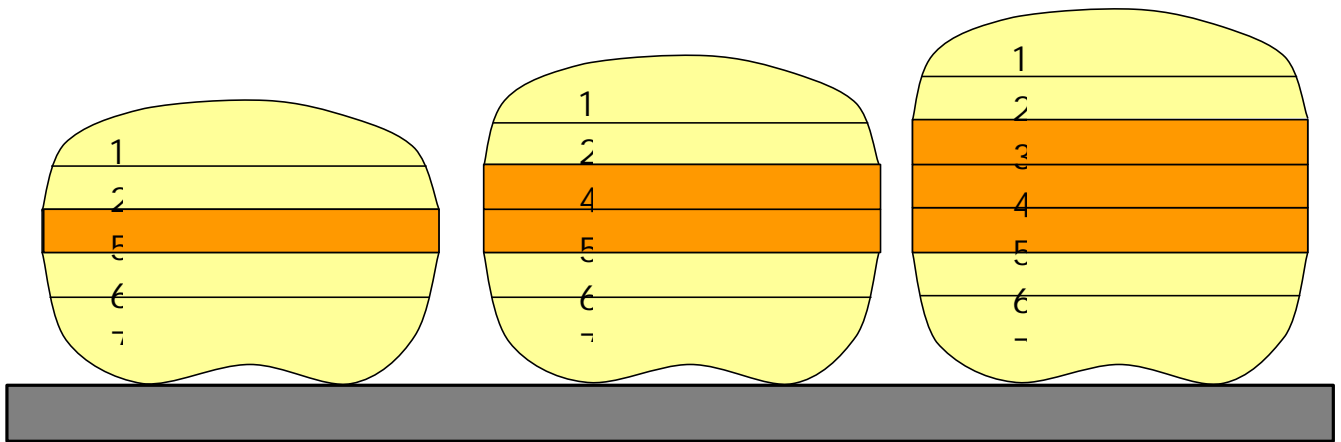


Figure 1: Anthropomorphic phantom with adjustable patient thickness (APAPT). Axial cut display to demonstrate the principle of the optional center sections.

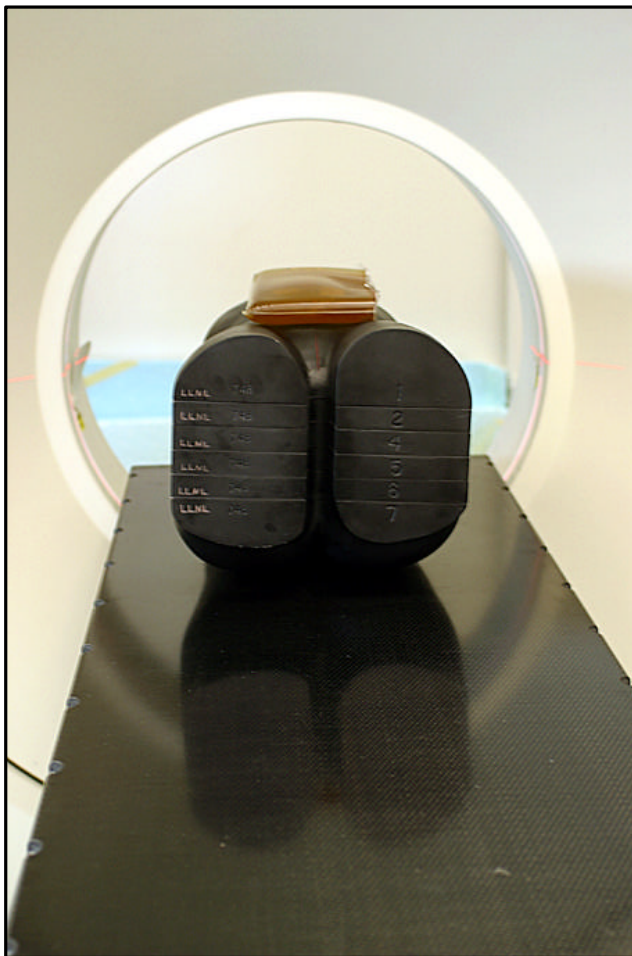


Figure 2: Photos of the RPHAT prototype at the CT scanner with bolus material

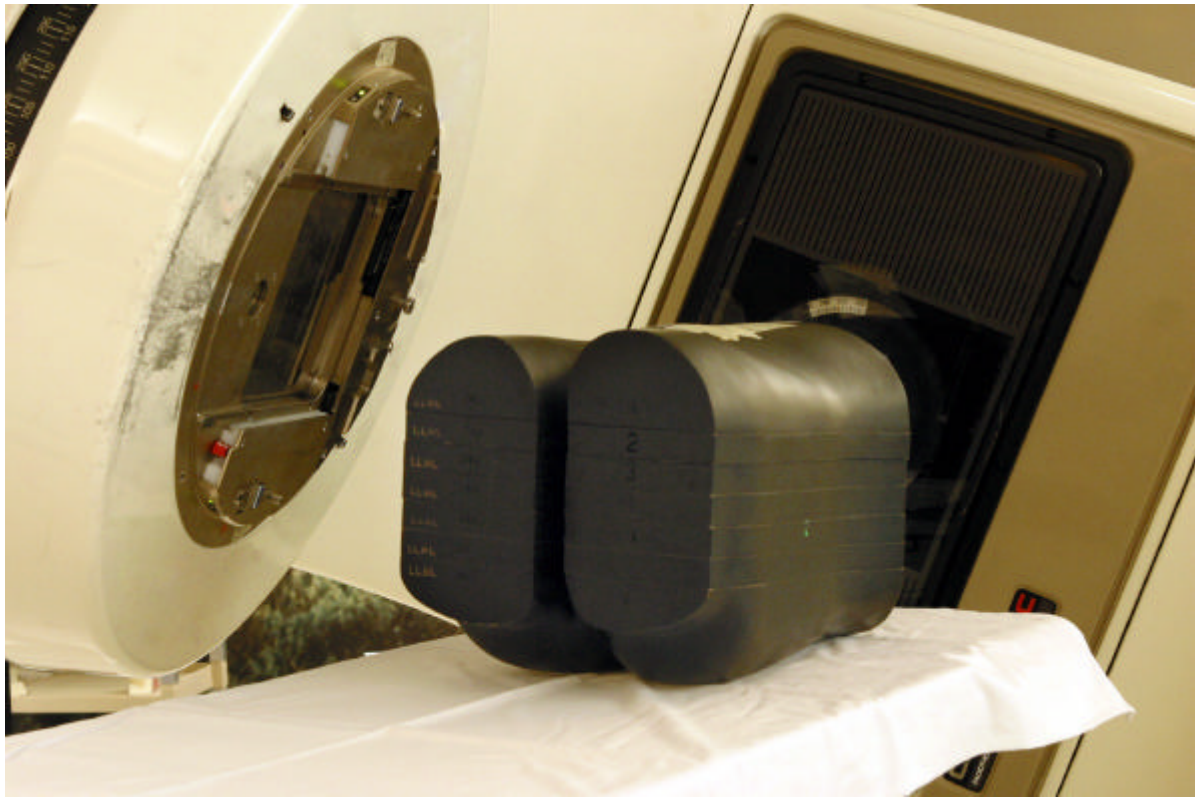


Figure 3: Photo of the RPHAT prototype at the treatment machine.